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INSTRUMENTS

THE MAGAZINE OF MEASUREMENT AND CONTROL

VOLUME 6 JULY, 1933 NUMBER 7

CONTROL PANEL FOR THE JACKSON STABILIZING PLANT, ATLANTIC REFINING COMPANY, PHILADELPHIA (Courtesy Foxboro Co.)

See Page 140

INSTRUMENTS

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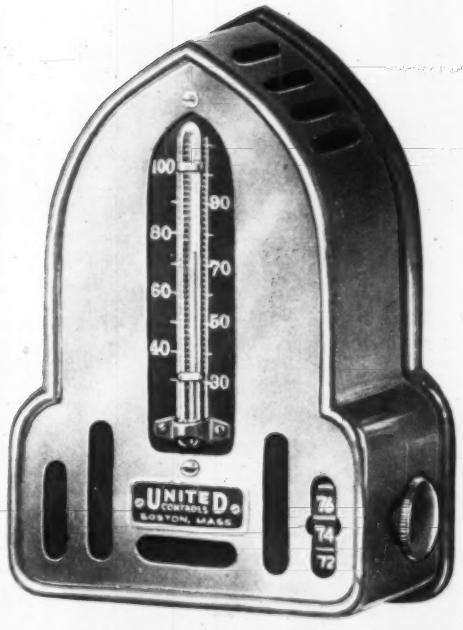
This UNITED THERMOSTAT



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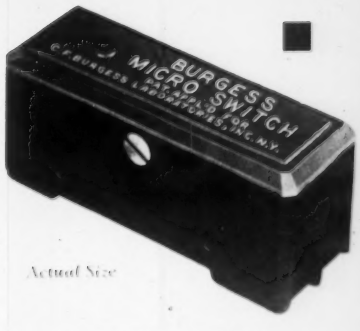

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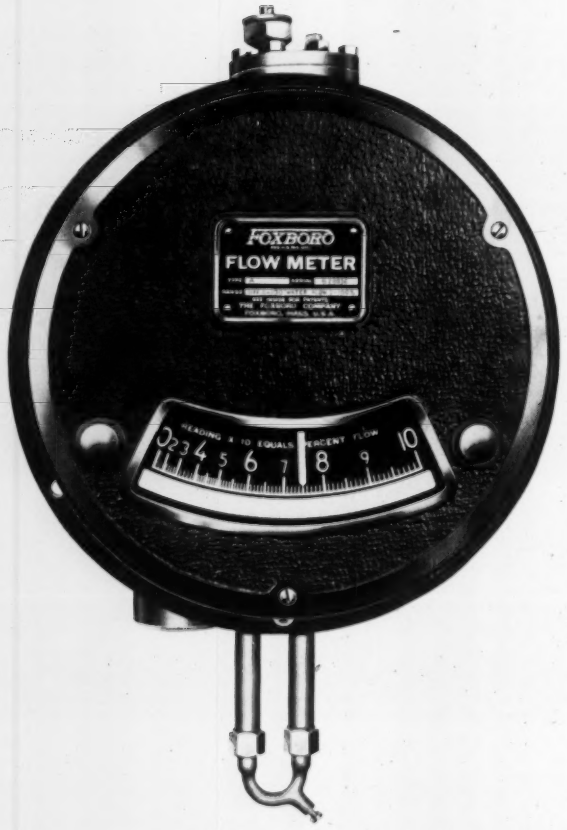

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EDITORIAL COMMENT

In This Issue

♦ Once more it is our privilege to publish the story of the evolution of a new instrument. **Walter C. Wagner** takes you behind the scenes in the leading feature article—a timely article, because recording demand meters seem to be coming to the fore in several fields of measurement.

♦ Speed regulation and overload protection are the aspects of **Control of Fractional-Horsepower Motors** discussed this month by **F. L. Spangler.**

♦ Some of **Prof. De Juhasz's** readers have indicators, use them frequently, and naturally desire to keep them accurate and well-calibrated. They may obtain a few valuable hints from what the Professor writes this month.

♦ Ordinarily, the bellows gas meter is "the forgotten instrument," but not in industry. Diehl, MacLean and Segeler contribute their expert views on industrial bellows meters to this month's installment of **Flow Measurement and Control.**

♦ Very few items in our **New Instruments** section this month—not because instrument firms have cut down on development work but probably because they recently were too busy filling your orders to send us the technical descriptions we specify. The last few days' mail before going to press, however, brought quite a number of write-ups, which now are in process of editing.

◈ ◈ ◈

The Next Issue,

therefore, will contain a brim-full measure of new instruments. It also will feature the brewery industry article we had expected to receive in time for July. Mr. Blodgett, the author, is the sort of chap who always strives for perfection, so you'll extend him a month's grace, kind reader, won't you?

◈ ◈ ◈

The Front Cover

♦ Progress in refinery practice goes on by leaps and bounds, thanks to Instrumentation. Our cover shows a control panel, but back of the good-looking instruments, there must always be good-working power devices, valves and other auxiliaries. Often it is these humble auxiliaries that make the performance of a job as good as its appearance!

Utopias . . . and You

HOW filled with wonders our troubled world would be if out of all the more or less fantastic schemes for re-composing it, a scanty half of one percent were put into effect! Self-appointed messiahs declare that men (other men) are incapable of self-government and that democracy is a failure. This is nothing new. Here and there on the face of the globe, now and then in the course of the centuries, governments change with startling suddenness. In some cases, the form of government is not altered but new laws affect the ordinary citizen or subject even more than would a *coup d'Etat.*

It is interesting to note that the fundamentals of measurement and control are as true in government, in sociology and in economics as in industrial instrumentation. To control any set of conditions effectively, it always is necessary (as the readers of *Instruments* well know) to measure them: "First measurement, then control."

The trouble with some leaders and with their henchmen is that, as instrumenticians would put it, they control by brute force and disregard factors which, inhering in each human "application," spell the doom of their schemes. These human nature factors are not exactly *measurable* by means of instruments but their positive or negative intensities are nonetheless *determinable.* Whenever and wherever they are not taken into account, control is "unstable."

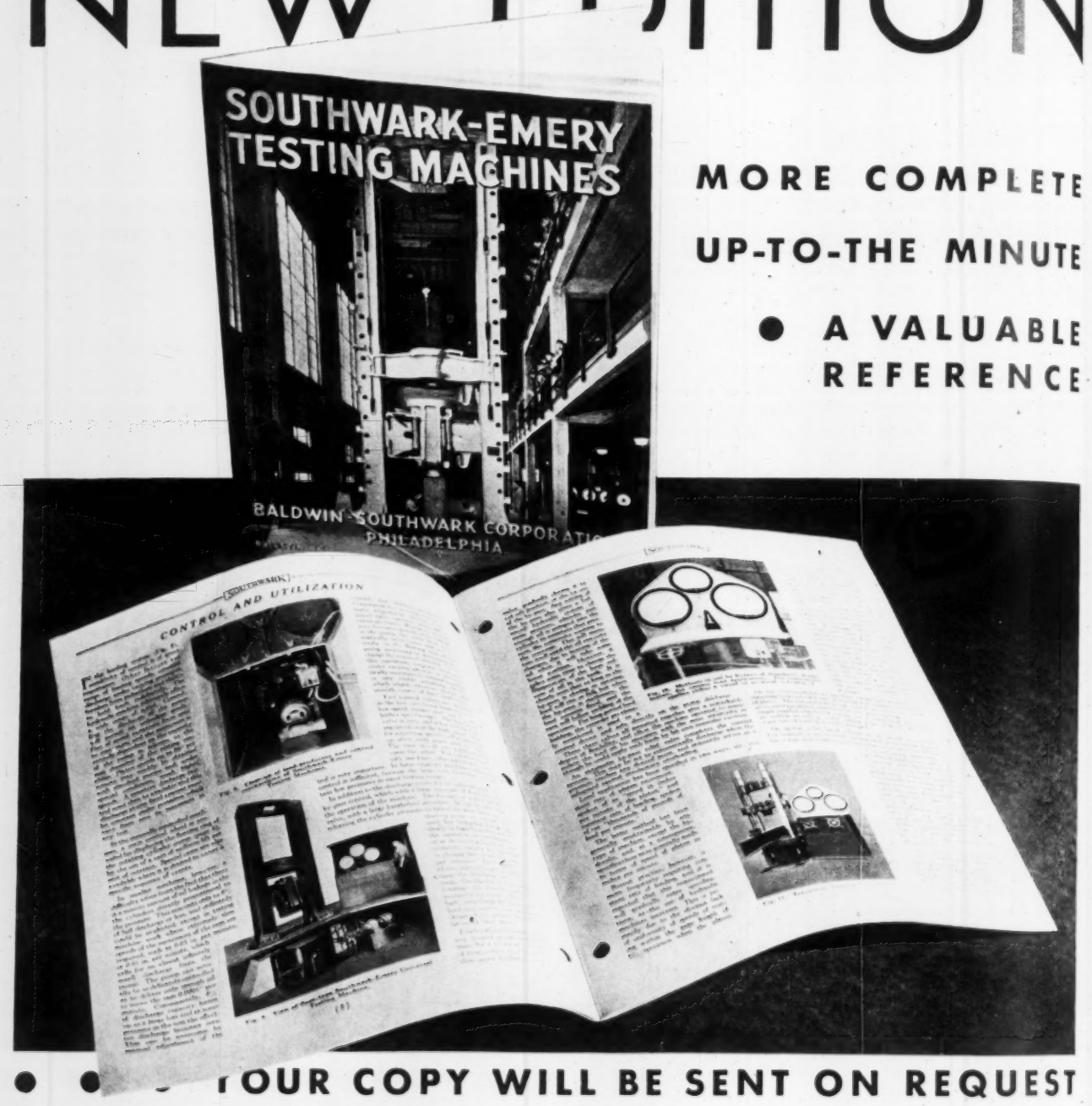
Lenin and Hitler provide two extreme examples of *force majeure* control thus doomed to failure. Lenin's utopia—communism—is predicated upon men and women utterly devoid of the desire for acquiring private possessions. Such a State may be kept going for years with the aid of brute force but it cannot endure unless the men and women in it become angels. On the other hand, Hitlerism is predicated upon the "wolf-pack" thesis—upon all men and women always finding joy in robbing and starving to death whatever brothers and sisters are designated as "enemies." This mode of control, likewise, cannot attain stability until the Nazi plan of abolishing Christianity is accomplished. All tyrannies resemble faulty-control applications where excessive power consumption is required to prevent the process running wild. Similarly, their over-size power cylinders (police forces) and elaborate wirings (spy systems) cannot achieve correct regulation: on the contrary, these inevitable features of despot control set up such stresses that the whole equipment eventually goes haywire. The pity of it is that every fanatical ruler either mistakes his tyranny for true regulation, or else cares nothing about it as long as he commands the power.

What can we do about it? Obviously, first of all spread the idea of a stable control of human affairs. Not, however, by scheming to become the "controllers." True, our methods of Instrumentation, if applied to human institutions, would result in efficient "non-hunting" control with a minimum of energy consumption and a maximum of satisfaction to all concerned, but, just as an expert in high-temperature control may not be familiar with gas pressure control, so we engineers as a class are not the ones to operate the throttles, relays, switches and rheostats of government. By setting a good example in the control of machines and processes, however, we can improve the control of political machines and economic processes. Let this—and not a technocratic State—be our definite goal.

M. F. B.

P. S. While each reader must do his bit in his own way and in his own field, there is one thing that all can do, and that is to increase the number of instrumenticians. If you induce two or three technical friends to subscribe to the magazine of measurement and control, the idea of measurement and control will receive a valuable impetus, contributing to human progress—indirectly and in small measure, but positively and permanently.

NEW EDITION



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SOUTHWARK

How a New Recording Demand Gas Meter Was Developed

By WALTER C. WAGNER*

A STRIKING example of results accomplished by co-operation of gas, steam and electric meter engineering personnel is the recent development of a gas demand metering equipment by the Philadelphia Electric Company. This came about by reason of the intimate personal contacts maintained among the departments concerned. The engineering division of the Gas Department has been working under the direction of L. B. Eichengreen, assistant to vice-president-in-charge of engineering, with the Operating Division co-operating, on problems involving the metering of gas demand. Paul Fusselman, superintendent of gas distribution, R. W. Pfaff, superintendent of the meter and testing section, and the writer, discussed the problem, and outlined the requirements which a demand attachment should meet when used with a bellows type, tin case gas meter. In general, it was found that such an attachment should meet, among others, the following requirements. It should—

1—be simple and certain in construction and operation and easy to maintain.
2—have unquestioned accuracy.
3—not impose an undue burden on the gas meter mechanism.
4—not carry lighting circuit voltage into or adjacent to the gas meter case.
5—be flexible in adjustmen to properly meter the demand of different size gas meters.
6—be able to register simultaneous demand of any number of meters in a group or any meter in a group.
7—preferably be able to also record the total gas consumption for the billing perfod as recorded by the demand meter, as a check on the dial readings of the gas meter or meters.
8—be able to record the demand for any desired time interval (such as for every hour or half hour).
9—where desired, give a graphic record showing well-defined demands for every demand interval, or, where desired, give only the maximum gas demand for the billing or test period.
10—have a construction which assures against gas leakage through the meter enclosure.
11—be readily adapted in construction to operate where electric service is not available.
12—be as tamperproof as practicable.

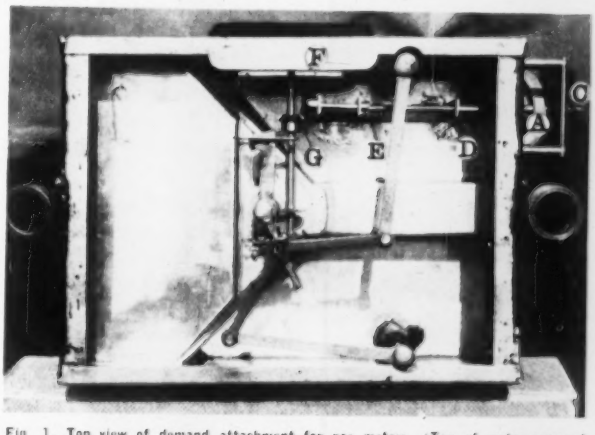


Fig. 1. Top view of demand attachment for gas meters. (Top of meter removed to show internal arrangement.) A—Permanent magnet. B—Cams for operating contacts. D.—Soft iron bar. E—Change gears. F and G—miter gears.

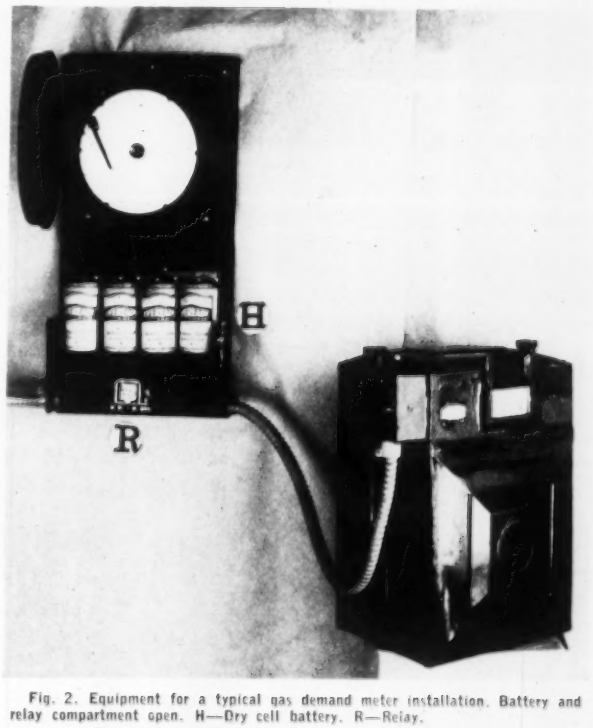


Fig. 2. Equipment for a typical gas demand meter installation. Battery and relay compartment open. H—Dry cell battery. R—Relay.

The general method by which an electrical measurement of gas demand is obtained follows:

The movement of the gas meter mechanism serves to rotate the dials of its register. The rotating element (in this case a rod) in the upper chamber of the tin case meter of the bellows type can be directly connected, or geared, to an electrical contact-making mechanism, the number of contacts being proportional to the number of revolutions of the rotating element of the gas meter. These electrical contacts, through connections to an electric demand meter, therefore, give a measure of the number of cubic feet of gas flowing through the gas meter for a desired time interval, as, for example, 15, 30, or 60 minutes. A graphic chart demand meter records the demand for *every* interval, while an indicating demand meter indicates only the *maximum* demand which has occurred during the billing or test period.

Among the earlier developments in this field should be mentioned an "Improved Type of Complaint Meter" described by G. S. Van Antwerp in the *U. G. I. Circle* of July-August, 1924, in which Mr. VanAntwerp, general superintendent of transmission and distribution in the suburban divisions of the Philadelphia Electric Company, then superintendent of the Northern Indiana Gas & Electric Company, describes an electrical attachment to record graphically the gas consumption over desired period of time.

The Connecticut Light & Power Company has recently developed a mercury contact device operated by a

*General Superintendent, Meter Division, Philadelphia Electric Company.

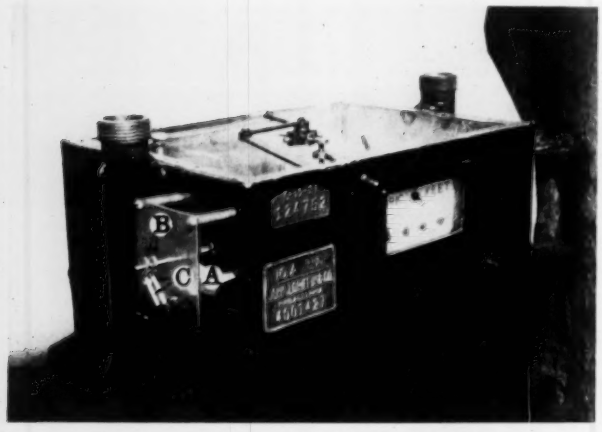


Fig. 3. Gas meter with demand contact mechanism operated by magnetic coupling device. A—Permanent magnet. B—Cams for operating contacts. C—Brush Contacts.

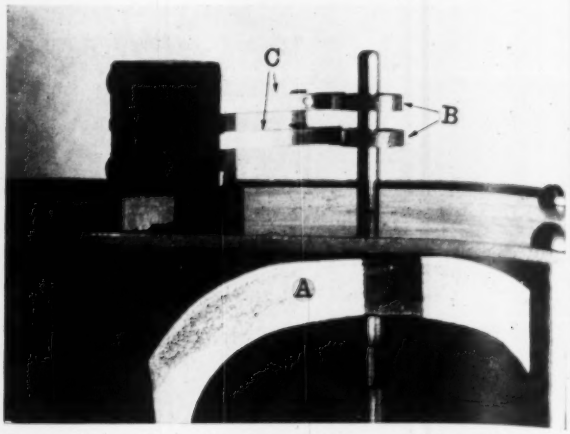


Fig. 4. Close-up of external contact mechanism operated by magnetic coupling device. A—Permanent magnet. B—Cams for operating contacts. C—Brush contacts.

rotating rod passing through the casing of the gas meter. Contacts are communicated to an electrical indicating or graphic demand meter.

Fred Strattner, supervisor of our meter laboratory, has now developed a new principle in which the magnetic linkage used in steam meters is adapted to gas meter demand requirements, thereby eliminating the use of a rotating shaft passing through the gas meter case. This, together with long experience in the development and use of demand equipment for electric meters, enabled us to readily meet the request of Mr. Fusselman for a number of gas meters completely equipped with demand attachments. The first model, built by Mr. Strattner, ably assisted by George Robertson, foreman of the meter laboratory, was submitted to H. B. Bryans, vice-president, and E. G. Boyer, general superintendent of gas operations, whose constructive criticism led to further improvements. The complete assembly with the gas meter operated by air was shown to President W. H. Taylor, H. B. Bryans, L. B. Eichengreen, E. G. Boyer, Paul Fusselman and G. E. Whitwell, vice-president, whose questions and suggestions resulted in betterments of the demand assembly. A description of the equipment in its final form follows:

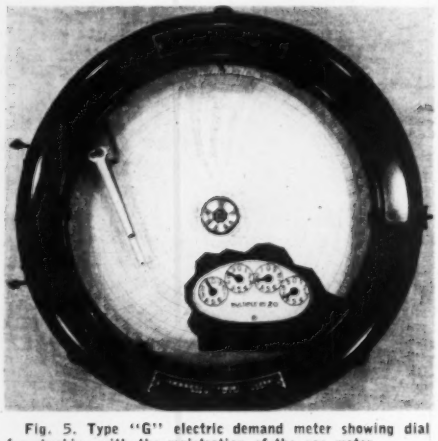


Fig. 5. Type "G" electric demand meter showing dial for checking with the registration of the gas meter.

An external contact-making device is magnetically coupled to a rotating shaft within the meter, thereby entirely eliminating the difficulties due to extending a rotating shaft through the case of the meter. While it would be possible to operate the demand meter directly from the contacts of the demand attachment, an additional safety feature is provided by the use of dry cell current rather than lighting circuit current at the contact device, so that no hazardous electrical conditions may occur at the meter.

Fig. 1 is a view of the open top of a gas meter with demand attachment applied. (A) is the rotating permanent magnet of the magnet coupling, which is mounted on an external shaft with cams (B), which operate contact brushes (C). The miter gears (F) and (G) serve to drive an internal demand shaft on which are provided change gears (E) for obtaining the desired demand constant, and a soft iron bar (D). In operation, the main drive shaft for the gas meter dial rotates the internal demand shaft, thereby rotating the soft iron bar (D). The poles of the permanent magnet (A) are mounted externally to the meter case, and a brass plate replaces that portion of the tin case within the field of the magnetic circuit.

Fig. 2 shows a typical installation of an unconnected gas meter, with a demand attachment and a type "G" electric demand meter. The cover of the service type cabinet has been opened to show the relay and dry cell assembly. The relay is operated by the flow of dry cell current through the demand contacts. In turn, the contacts of the relay control the operation of the demand meter. Where only the maximum demand for the period is required, an indicating demand meter may replace the graphic type.

Fig. 3 shows an external view of the gas meter (top opened) with the demand contact mechanism in the foreground. (The same reference letters are applied to the same parts in all illustrations.)

Fig. 4 is a close-up of the external device, showing the permanent magnet (A) with standard electric meter demand cams (B) and contact brushes (C). Mercury switches may be used, but are unnecessary, as only battery voltage (4 to 6 volts) exists at the contacts.

Fig. 5 shows a close-up of the type "G" graphic electric demand meter with 32-day chart. Note that the "zero" of the scale is at the outer periphery, thereby more definitely recording the individual hourly readings. The dial register in back of the chart serves as an indication of the number of contacts which have been made by the demand attachment. This reading serves as a check on the gas consumption as recorded by the gas meter, and verifies the proper operation of the demand equipment.

This device, or an adaptation, is equally applicable to the flow type of meter for any gas or liquid, and would operate as now applied to steam flow meters.

Control of Fractional-Horsepower Motors

By F. L. SPANGLER*

(Continued from June issue)

Speed Regulation

Small motors driving tools, fans, pumps, and other types of appliances are frequently required to operate at varying speeds, depending upon the requirements of the service or the nature of the work in process. It is a well-known fact also that motors designed to be interchangeable on a.c. and d.c. circuits are necessarily of the series-wound type and therefore have a speed characteristic which varies approximately inversely with the load, which is not desirable in applications requiring constant speed.

Means for obtaining speed regulation of fractional-horsepower motors are so many and varied, particularly with d.c. motors and series-wound motors, both a.c. and d.c., that only the most common methods will be mentioned.

A.c. and d.c. series-wound commutator-type motors are usually varied in speed by inserting in series with the motor a speed-regulating rheostat, the resistance of which is varied by hand. If the load is fixed, an increase in resistance reduces the motor speed, and when the resistance is decreased, the motor speeds up. Another common method of regulating the speed of these motors is to shunt the armature with a variable resistance; to reduce the speed, the resistance is decreased, which increases the strength of the motor field. At low speeds, the lowered resistance shunted around the armature results in a heavy field current and a saturated field, which causes the motor to perform more nearly like a shunt-wound motor, so that the motor speed does not vary as greatly with load changes as when a series rheostat is used for speed regulation.

To obtain an unvarying speed, series-wound motors can be equipped with a governor actuated by centrifugal force. This governor is set to maintain the motor speed at some constant value, and it is so sensitive to speed changes that its contacts may open and close many times per second. A slight increase in speed above normal opens the contacts and inserts a fixed step of resistance in the motor circuit, causing the motor to slow down. As the speed decreases below normal, the contacts close and shunt the resistance out of circuit, causing the motor to speed up. The rapid action of the governor maintains the motor speed at a constant value.

With the shunt-wound d.c. motor, an increased resistance in the armature circuit results in a reduction in the speed, irrespective of load changes, while an increased resistance in the shunt field causes the motor to speed up. Therefore, with rheostats in both the field and armature circuit, the speed can be varied over a wide range of values falling above and below the speed obtained with rated voltage impressed on both the field and armature windings.

Resistors used for speed regulation will be in circuit most if not all the time the motor is operating. Therefore, they must be able to dissipate heat more rapidly than starting resistors, and are generally rated for continuous duty. High heat-dissipating capacity is especially necessary where the rheostat is in series with the motor armature. Field control rheostats, on the other hand, are subjected only to the small shunt-field current, and therefore do not heat up much, and are more economical in power consumption.

Series rheostats for the speed regulation of motors may be of the face-plate type with a radial lever which slides over a series of contacts. This rheostat, which is somewhat similar in design to that shown in Fig. 24, is connected in series with the motor armature, and the spring-return lever is held in any of the various speed positions as long as the hold-in coil is energized. If the line voltage fails or the shunt field is opened, the face-plate lever automatically returns to its "Off" position and opens the motor circuit. Speed control rheostats for connection into the shunt-field circuit are often of the face-plate type, and the resistance is varied by turning a hand knob. With the face-plate type of rheostat, as many speed points can be obtained as there are contacts. Each speed point is fixed by the design of the rheostat, and hence slight variations in speed control cannot be obtained.

To obtain stepless variation in speed control, the compression type of resistor can be used. The graphite compression resistor shown in Fig. 27 has a sufficient thermal capacity for the speed control of motors up to ¼ h.p. capacity. This resistor can also be supplied in larger and smaller sizes than the one shown.

A treadle-operated speed controller equipped with graphite compression resistors is shown in Fig. 28. A shaft, not shown, extends from the eye at the lower end of the compression rod down to a treadle located on the floor. The controller itself may be mounted on the underside of a table or machine housing. To bring the motor up to speed, the treadle is pushed downward by the foot. The first movement of the treadle causes a snap-action switch to close, completing the motor circuit through the resistors. As the treadle is further depressed, greater pressure is applied to the columns of graphite disks, and the motor speeds up. The exact speed desired can be obtained by applying the proper pressure on the treadle. When full pressure is applied, a pair of contacts close, shunting the resistors out of circuit. Fig. 29 shows a controller which operates on the same principle as that just described, but is of much smaller capacity, being designed for the speed control of domestic sewing machines. The entire control and treadle are combined into a unit which lies on the floor convenient to the operator's foot.

Overload Protection

When motors do not dissipate heat as rapidly as it is received in the form of I^2R losses and losses due to eddy currents and hysteresis, the windings necessarily heat up. The greater the current drawn by the motor, the higher will be the temperature of the motor windings. The rate at which the motor dissipates heat depends on the temperature difference of the motor and the air in the room where the motor is operating as well as on the effects of fans and other means of artificial ventilation. A motor carrying a given overload will overheat sooner when operating in a hot boiler room than if it were operating under normal conditions of room temperature. In fact, a sustained high current may overheat the motor under certain conditions and not under others. When overloads, therefore, are spoken of in terms of amperes, the conditions of room temperature and ventilation must be known.

It is usual to rate general-purpose motors of the open type on the basis of the maximum load that can be carried without the temperature rise exceeding 40° C. above the surrounding atmosphere, when operating at rated voltage and frequency

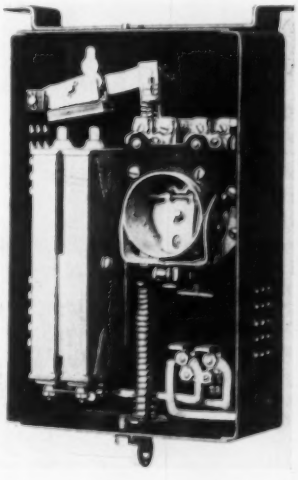


Fig. 28. Treadle-operated speed controller with cover removed showing snap-action switch and compression resistors. Operation is by means of a vertical shaft which can be attached to a treadle located on the floor in front of the operator.

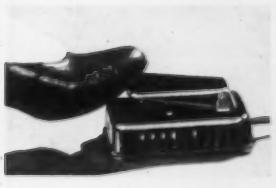


Fig. 29. This treadle-operated controller is of the same general design as that shown in Fig. 28 but is of smaller capacity. Many thousands of these are being used with domestic sewing machines to obtain accurate speed control.

with an ambient room temperature of not more than 40° C. Therefore, with maximum ambient temperature and continuous rated load, the motor temperature will not exceed 80° C. All currents above rated full-load current are known as overload currents.

Heavy overload currents occur when motors are started across-the-line without resistance in the motor circuit to hold the starting current to a low value. This overload is of short duration and usually does no damage to the motor winding. Also, many other types of overloads met with in service are of short duration. Where such overloads are not sustained, the motor has an opportunity to cool off before the next overload occurs.

The purpose of overload relays is to protect the motor against damage from continuous overload currents. If the motor starting switch opened every time an overload occurs, it would be impossible to start the motor except with resistance in series, since the current inrush when starting across-the-line is an overload current; and overloads even of short duration would cause the switch to open and disconnect the motor from the line, although the temperature of the motor windings might still be far from the danger point. To obtain adequate overload protection of motors, it is not necessary that the motor be disconnected from the line every time an overload occurs, but the motor starting switch should open before the overload has been sustained to the point where the motor windings would be damaged by the heat. Small or temporary overload currents, therefore, should not cause the overload relay to trip immediately, and the time of tripping of the relay should depend on the magnitude of the current—that is, the greater the current, the sooner the relay will open the switch and disconnect the motor from the line, but where the overload is of short duration, such as when starting the motor, the relay should not trip.

The overload relay also effectively protects polyphase motors against damage due to single-phase operation, in case one phase is out of commission, since the current in the live phase winding becomes an overload current and causes the overload relay to trip. With d.c. and single-phase motors, one relay usually provides adequate protection; polyphase motors, on the other hand, require 2 relays whether for two- or three-phase service. When these relays are supplied on starting panels enclosed in a cabinet, reset levers are provided in the cabinet cover so the relays can be reset without opening the cabinet.

The contacts of overload relays are always in series with the hold-in coil of the magnetic switch, as shown in the diagrams in Figs. 5, 6, 26 and 36. Hence, when any of the overload relays trip, this circuit is broken, the coil is no longer energized, and the switch opens. For small motors, overload relays are usually of the resistance type, which supplies adequate protection for all conditions arising in small-motor service.

◆ ◆ ◆ ◆ ◆

AT the Gulf Research Laboratory, Pittsburgh, the need arose for installing two instruments permanently on a motor-driven centrifugal pump. One instrument was to be a revolution counter; the other a remote-reading tachometer. R. J. S. Pigott and Abbot A. Lane, the engineers concerned, decided against purchasing two specialized instruments. Instead, they ordered a standard magnetic type automotive odometer-speedometer modified only in that the scale cup was to read r.p.m. instead of m.p.h. Months of continuous operation have developed no trouble. Speed indications are satisfactorily accurate and always verifiable when the motor runs at constant speed.

◆ ◆ ◆ ◆ ◆

To the Manufacturers:

In order to keep the readers of INSTRUMENTS in touch with the latest developments in instruments and devices for measurement and control, the editor again urges all manufacturers of such instruments to keep him informed of all new devices or important improvements made as soon as they appear, by letting him have descriptions of about 1000 words covering construction, performance, and applications, together with suitable diagrams and photographs.

A Book Ad *Written by Critics*

[Extracts from reviews in more than fifty technical journals.]

BRIEF GENERAL DESCRIPTIONS

"Handbook of Industrial Temperature and Humidity Control, by M. F. Behar; cloth; 6x9¼ inches; 320 pages, 278 illustrations; $4. This excellent publication constitutes, respectively, Part Two and Part Three of the Manual of Instrumentation." [1]

"If one disregards this formal division, however, one notes that the volume comprises not two but four separate 'handbooks' (of which three are original treatises), plus two chapters both pertaining to all four handbooks, and nine appendices of which seven pertain to temperature and two pertain to humidity. These four 'handbooks' deal with subjects of prime importance to industry: (1) thermometry, (2) pyrometry, (3) automatic control of temperature, and (4) humidity measurement and control." [2]

"A great amount of detailed information is presented upon thermometers, pyrometers, heat recorders and controllers, and instruments for measuring and controlling humidity. The presentation is intensely practical and will be helpful to all students of these subjects." [3]

"Between a discussion of what is temperature, and a host of valuable tables and charts, he sandwiches some 300 pages of well-ordered information on every conceivable device having to do with temperature or humidity. The multitudinous phases of the subject he deftly breaks up into logical groups and devotes a chapter to each." [4]

"Not only has the material been contributed by a large number of cooperating specialists, but the determination of the contents was governed by a consensus of reports as to existing needs." [5]

"Another long-felt and serious need, especially acute in the heat-treating and metal industries has been for a practical text on pyrometry." [6]

"The third major subject is *temperature control* and here the author had to break new ground, for despite the fairly voluminous literature on control *devices* there had never been published any treatment of control *technology*." [7]

"The volume is of particular value because of the comprehensive discussion of humidity." [8]

COMMENTS ON TREATMENT

"Apart from the main essential of technical accuracy and thoroughness, the method of handling is free, entertaining, and readable—an unusual and much needed feature of most technical literature. The author avowedly believes and acts on the principle that applied physical science should be humanized and treated more or less informally like any branch of human knowledge." [6]

"Lucid style and freedom from confusing technically-worded sentences." [4]

"The presentation is understandable and the text is comprehensively illustrated." [9]

"The entire volume is written so well that no technical man need have difficulty in utilizing either the principles or details. In spite of being written for the 'production men' it is of sufficiently wide scope to be useful to many persons engaged in research and might serve as a textbook in technical courses. Much of the material is excellently presented in tabular form. Often compilations of material submitted by experts are used." [10]

"Indeed, the most remarkable feature of this book is the extremely interesting and simple manner in which the author clarifies the complex principles . . . One is struck by the human interest that can be put into a subject usually considered dry and uninteresting." [11]

"All in all, this is an outstanding work, possibly the most notable technical book that has passed the editor's desk this year." [3]

"It is seldom that we find a book which we can so wholeheartedly recommend to our readers as this one, which contains so much information and so much evidence of careful preparation that we wonder how it can be offered at so small a price." [12]

"Covers a singularly broad field in fairly compact manner." [13]

"This book succeeds well in its aim of telling concisely the theoretical background, the actuating principles, the various details of design and the scope, with limitations, of instruments for measuring and for controlling both temperature and humidity." [14]

[1] *Industrial Record*
[2] *Heat Treating and Forging*
[3] *Mechanical Engineering*, also *Mining & Metallurgy*, also *Electrical Engineering*
[4] *Electric Journal*
[5] *S. A. E. Journal*
[6] *Gas Age-Record*
[7] *Drugs, Oils & Paints*
[8] *Engineering & Mining Jnl.*
[9] *Paper & Paper Products*
[10] *Review of Scientific Instruments*
[11] *Product Engineering*
[12] *Heating & Ventilating*
[13] *Chemical & Metallurgical Engineering*
[14] *Electrical World*

Instruments Publishing Co.

330 WEST 42nd STREET, NEW YORK

The ENGINE INDICATOR

Its Design and Theory

By KALMAN J. DeJUHASZ*

(Continued from June issue)

TESTING AND CALIBRATING THE INDICATOR

It is evident that a diagram which represents with fidelity the working process of an engine or machine can be obtained only with an indicator made accurately to start with and maintained in a condition as free from faults and defects as possible. The conclusions drawn from an incorrect diagram may be entirely misleading. The stresses, wear and tear, and accidental damage to which the indicator is exposed in its use make it necessary to test its condition and calibrate it from time to time. The friction and backlash in the piston and recording gear, the misalignment of the drum axis and the defects of proportionality of the drum drive have been dealt with in previous chapters. The methods for determining the actual spring scale, the knowledge of which is most important for the correct interpretation of the diagram, will be dealt with in the following.

The magnification ratio of the recording gear can be determined by displacing the piston by a known amount and noting the displacement of the pencil point. This can be accomplished with the aid of a micrometric depth gage as shown in Fig. 113.[33]

The spring scale, stamped on the foot of the spring, is only approximate; furthermore it is subject to alteration as the elastic properties of the spring change with time as a consequence of repeated stresses.

The spring can be calibrated by *pressure* or by *weight.*

In pressure calibration the indicator piston, loaded by the spring, is subjected to a variable pressure which is measured accurately by a Bourdon gage or by a dead weight gage. With this method, therefore, the actual piston diameter need not be determined, as the pressure is measured directly. The small steam boiler, shown in Fig. 114 serves for this purpose and has the advantage that the temperature of the indicator and therefore the piston area will be approximately the same as that attained in its actual operation on a steam engine. (The piston area increases about 0.2% for every 100° F. increase in temperature.) This method is therefore preferable for internal spring indicators. With the increasing adoption of the external spring indicators this method has lost some of its former importance. In the gage tester shown in Fig. 115 oil (or glycerin-water mixture) is put under pressure by a plunger of known cross sectional area loaded by known weights. Axial friction of the plunger is eliminated by spinning it, together with the stack of weights, before each calibration line is traced on the indicator. This method becomes cumbersome and even altogether impracticable at large pressures.

The apparatus shown in Figs. 116a and b (developed at the Engineering Experiment Station of The Pennsylvania State College) eliminates the handling of heavy weights by measuring the plunger force through a system of levers by a pendulum balance. From the known area of the plunger, from the known leverage ratio of the balance levers and the weight shown on the balance scale the oil pressure can be determined. The plunger and its companion bushing are made of hardened steel, carefully ground and lapped to a sliding fit. A body of solid steel is provided with drilled passages connecting a number of openings. Through one of the openings the body is connected to a high pressure oil pump; into another opening is secured, by means of a union screw and copper gasket, the bushing into which the plunger

*Asst. Prof. of Engineering Research, Pennsylvania State College.

[33] This subject is treated in detail in: H. F. Wiebe und A. Leman. Untersuchungen ueber die Proportionalitaet der Schreibzeuge bei Indikatoren. *Forschungsarbeiten des Vereines deutscher Ingenieure.* No. 34, 1906, 10 pages.

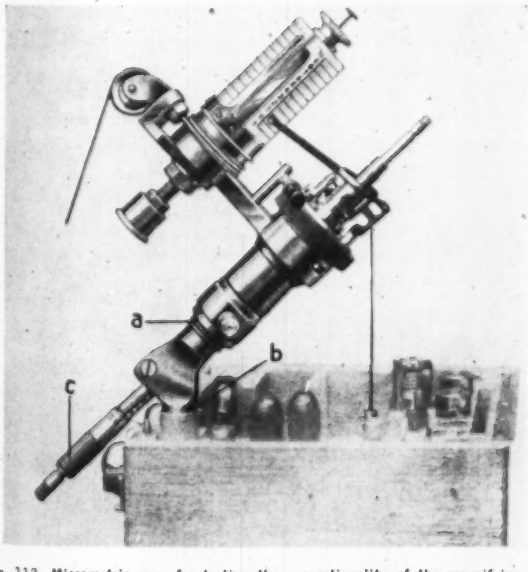


Fig. 113. Micrometric gage for testing the proportionality of the magnifying gear. (Maihak.) The body *a* screws into the indicator union nut and also fits into a conveniently arranged socket in the indicator box. Into this body the micrometer *c* is clamped.

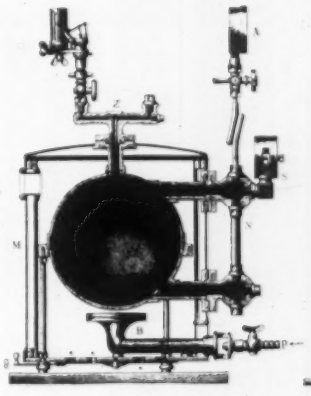


Fig. 114. Steam boiler for calibrating the indicator spring. K—Boiler; B—Gas Burner; A—Master Pressure Gage; Z—Fixture upon which the indicator is mounted.

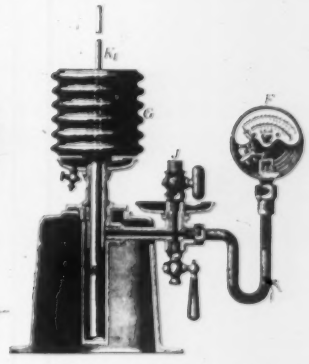
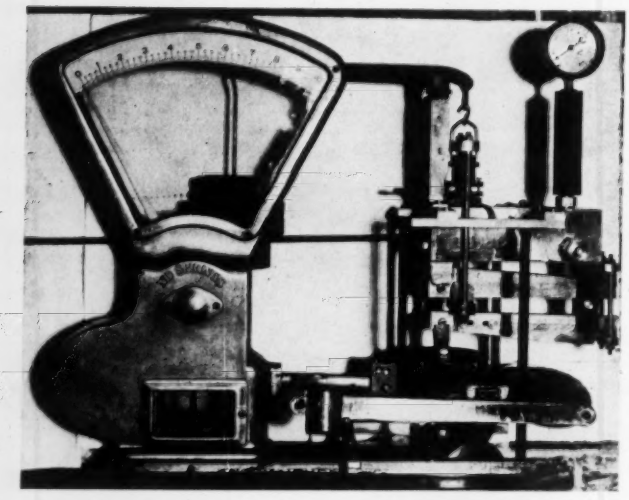


Fig. 115. Hydraulic pressure gage tester. K—plunger; G—weights; F—Master Pressure Gage (not necessary, but desirable for check); J—indicator cock.



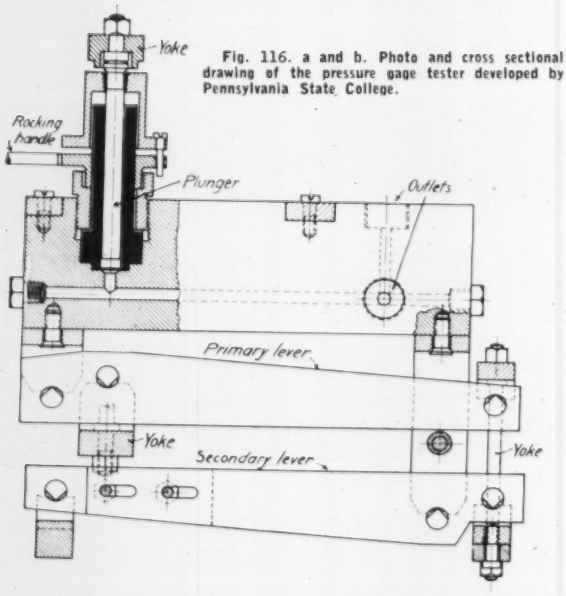


Fig. 116. a and b. Photo and cross sectional drawing of the pressure gage tester developed by Pennsylvania State College.

is inserted; two other openings are provided for attaching the indicator, or pressure gage to be calibrated. Subjected to oil pressure the plunger develops a vertically upward directed force which is transmitted, by means of a yoke, to a one armed lever, the far end of which bears in turn on the short arm of a two armed lever. The length of this latter is adjustable and presses on the pan of the pendulum scale. The weight of the plunger, yoke and levers is compensated by means of an auxiliary lever upon which the tare weight is hung. A smaller weight, riding on the arm of the pendulum scale, serves for fine adjustment, in order to bring the pointer to zero when no fluid pressure is applied. The leverage ratio is harmonized with the plunger diameter in such a way that 2 lbs. on the scale represents 1000 lbs./in.^{2} pressure acting on the plunger and on the apparatus being calibrated. The sliding friction of the plunger is eliminated by oscillating it with a handle.

In the *weight calibration method* the spring is loaded, through the indicator piston rod, by weights as shown in Fig. 117. The weight divided by the piston area (which has to be measured accurately) gives the corresponding pressure. The objection is raised against this method that an error in the assumed or measured piston area would vitiate the result, and also, that the effective area which lies between the area of the piston and that of the cylinder, cannot be known with certainty. In view of the high accuracy, however, with which the cylinders and pistons can be produced, and of the extremely small clearance between them, these objections lose much of their force. The fact is, that owing to its convenience of operation this method is used in most cases. Such weight calibration apparatus has been built (Lehmann and Michels) embodying a steam heating arrangement in order to eliminate the temperature errors. However, such refinement is generally not considered necessary, save under exceptional conditions.

In order to avoid the cumbersome handling of heavy weights a lever type weight-calibration apparatus has been developed by the Maihak Co. (Fig. 118) especially for the calibration of their cantilever spring type high speed indicator. This embodies a 1:10 leverage ratio for the weights, an arrangement for arresting the lever when the weight is changed and a drum actuating mechanism for drawing the calibration lines.

The distance between the calibration lines can be measured by an accurate scale which is sometimes made of glass for this purpose. A very great accuracy can be obtained by means of a comparator.

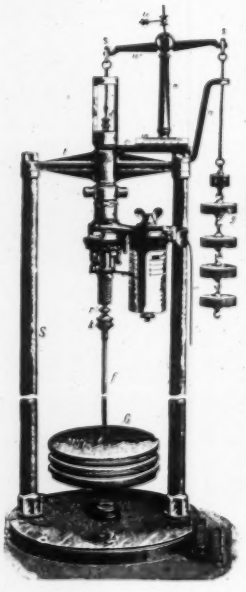


Fig. 117. Weight calibration stand for indicator springs. G—weights for tensioning the spring (pressure); g—weight for compressing the spring (vacuum); i—tare weight; r—leveling screws; l—water level.

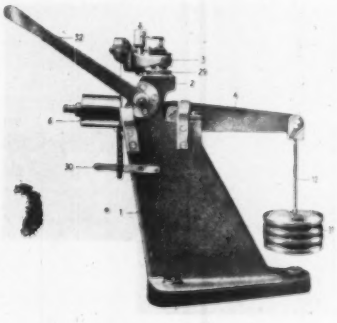


Fig. 118. Weight calibration stand for cantilever indicator springs (Maihak). 1—frame; 4—lever; 31—weights; 6—counter weight for tare; 3—cantilever spring indicator; 32—arresting lever; 30—lever for rotating indicator drum.

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Flow Measurement and Control*

By M. F. BEHAR†

CHAPTER XXIII

POSITIVE METERS
(*Continued*)

POSITIVE GAS METERS

10. Bellows

(a) General Characteristics

The first reliable two-diaphragm slide-valve meter to be produced on a large scale was that of Thomas Glover & Co., Ltd., whence the designation "Glover type meter" for this general type, but its inventors were Croll and Richard, in 1844. No essential change has been made in this bellows type since then, but countless improvements and refinements have made possible Diehl's recent assertion, "All things considered, the gas-meter is the most reliable instrument made."

Certainly, *reliability* is an outstanding characteristic of bellows meters—even of the smallest and cheapest domestic meters, as witness the fact that in States where an accuracy of $\pm 2\%$ is obligatory, a seven-year interval between regular inspections proves satisfactory.

Unvarying proof over a wide range of flows is another general characteristic of all sizes and types of bellows meters, but in this respect the larger sizes show up much better than the residence meters, passing rigorous "pilot light" tests. It is not uncommon for a "150A" (3400 cu. ft. per hour at 0.5" pressure loss) to register 99.5% when operated at 0.5% of its capacity load.

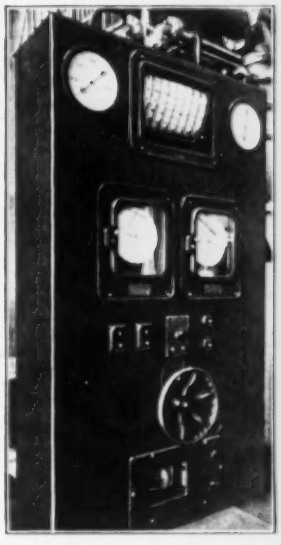
Likewise with retention of accuracy over long periods of time: all sizes and types of bellows meters hold their proof with an average drift of $<0.4\%$ per year, but the larger sizes—especially the larger sizes of the iron case types, with roller bearings, dust caps for bushed bearings above the table, and other refinements—show a much smaller proportion, at the end of a seven-year period, of meters that are $>2\%$ fast or slow.

As to the question of *accuracy*, it could be disposed of by saying that bellows meters, when operated within their capacity range, can be adjusted to within $\pm 1\%$ of perfect registration, but this brief statement is predicated on the uses of meters rather than on their intrinsic accuracy; and moreover it lacks completeness in that other factors than normality of load contribute to over- and under-registration.

We are not referring here to gas pressure or temperature being different in service from what they were in the proving room, nor to any other external factors, but only to strictly intrinsic factors: changes within the meter. Of these, the changes in properties of *diaphragm leathers* are the most important, and a point to bear in mind is that if the metered gas differs in its constituents from the proving medium, it may either add to or take away from the volatile impregnating compounds which determine the pliability of the leathers. In the nature of things, it is impracticable to make the highest quality leathers less sensitive to this effect than the cheapest. Therefore, it is precisely in the case of the high-grade industrial meters that users should watch out for changes in the "fog" content of metered gases—not because the leathers of these meters are more readily affected than cheap leathers, but because engineering requirements are more exacting. To give a comparison: Slight seasonal changes in the saturation of manufactured city gas which cause all consumers' meters to register approximately 0.4% faster or slower are of no interest to the utility consumers themselves, whereas in industrial process work involving gas measurement, an engineer who expects that the proof of a particular meter will not change by more than 0.2% will not fail to take notice of an effect which frequently causes greater changes of registration, especially when the extent of these changes is always so uncertain that he will never know how much to allow for.

*Part Six of *The Manual of Instrumentation.*
†Editor, *Instruments.*

FOR BOILER CONTROL



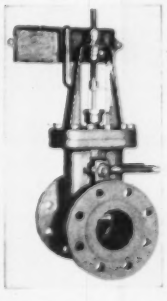
THE BAILEY BOILER PANEL gives complete information for controlling boiler operation. It contains the Bailey Boiler Meter, a Bailey Fluid Meter with which is combined a Boiler Water Level Recorder, and a Bailey Multi-Pointer Gage. The operator has everything right before him to obtain the desired capacity and best efficiency at all times. Request recommendations for your boilers.

PRESSURE GAGE

Extremely accurate gages embodying the dead weight gage tester principle are available in several sizes up to 36" in diameter for indicating at remote points the pressure of steam, water, gas, etc. These gages can be used with any pressures and are particularly suitable for magnified ranges. Ask for Bulletin No. 70.

LONG DISTANCE INDICATOR

Bailey Meter Selsyn Operated Equipment for recording and indicating pressure, temperature, draft, liquid level, etc. at any distance from the source is highly accurate and reliable. Described in Bulletin No. 110.



ADJUSTABLE ORIFICE

The Bailey Adjustable Orifice is for use with Fluid Meter installations where accurate measurements are desired over a flow range of as wide as 160 to 1. Ask for details.

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MANUFACTURERS' LITERATURE

—In this department we each month list the printed matter issued by manufacturers. Unless otherwise noted, any of the items listed may be secured free upon application to the issuing firm. Manufacturers who have not yet sent in their printed matter are invited to do so.

A165 **Simple Testers.** Circular No. 107 describes a new portable Bursting Strength Tester, new Tensile Strength Testers, a new Pocket Thickness Gage—all designed for rapid testing of materials as paper product supplies, cordage, rubber, wire, etc. Amthor Testing Instrument Co., Inc., Brooklyn, N. Y.

A166 **Mercoid Switches.** Bulletin No. 500 describes Mercoid switches for all applications requiring electric contact. The Mercoid Corp., Chicago, Ill.

A167 **Automatic Controls.** A new binder set of bulletins on various devices embodying mercury switches. The Mercoid Corp., Chicago, Ill.

A168 **Gyroscopic Instruments.** 20-page booklet entitled "Flying with the Sperry Horizon and the Directional Gyro." Also the April 1933 "Sperryscope" of which the feature article is "A Gyro Compass for Every Ship." Sperry Gyroscope Co., Brooklyn, N. Y.

A169 **Microscopy.** May 1933 "Microscope Record" contains several natural history articles, also one on "Dark-ground Illumination." The May 1933 list of second hand microscopes and accessories runs to 16 pages. W. Watson & Sons, Ltd., London, England.

A170 **"Ohmite News."** May 1933 issue describes new 300-watt rheostat. Ohmite Mfg. Co., Chicago, Ill.

A171 **Balances, etc.** 44-page Catalog B1 covers analytical balances, weights, balance accessories and certain laboratory specialties such as the "Fixanal" volumetric solutions, test papers, the "Wulff" hydrogen ion determination apparatus and "Kolthoff" buffer tablets. Pfaltz & Bauer, Inc., New York.

A172 **Insulation Testing Instruments.** Bulletin 1355 describes 5 different types and 40 ranges of the "Megger" instruments, also some other instruments. James G. Biddle Co., Philadelphia.

A173 **"Sperry Detector."** Vol. III No. 2 has article on "Four Years of Progress in Rail Testing." Sperry Products Co., Brooklyn, N. Y.

A174 **Control Pyrometer.** Broadside on Wilson-Maeulen Div.'s potentiometer controller. The Foxboro Co., Foxboro, Mass.

A175 **Microscopes.** 12-page bulletin (in Italian) on improved "Dermatocapillariscopio" biological and bacteriological equipment with new accessories and illuminators. Officine Galileo, Milan, Italy.

A176 **Vibrograph.** 16-page bulletin (in Italian) on new film-recording Vibrografo Ganz. Officine Galileo, Milan, Italy.

A177 **Direct Reading Form Factor Meter.** 4-page bulletin (in Italian) on "Vecchiacchi" instrument. Officine Galileo, Milan, Italy.

INSTRUMENTS, 330 W. 42nd St.
New York City

Please have me supplied with a copy of each piece of Manufacturers' Literature listed below.

.....

.....

Name.....

Position.....

Firm.....

Street and No.....

City.....State.....

One extreme example of variance from this cause is that resulting from changing from an oil-rich gas to a dry gas, or air, so that leathers that were saturated with "meter condensates" dry out and stiffen to such an extent that the displacement constant of each chamber may be reduced by as much as 2%, making the meter 2% faster.

Another extreme example might be furnished by the same meter, subjected to the same change-over from oil-rich gas to air: it may well be that its leathers will soon begin to leak at the seams and before long develop cracks at the annulus of greatest flexure, until eventually the meter may register slow at normal load and fail altogether to register at low rates of flow.

Leathers being thin, it takes little time for their volatile oil content to come to equilibrium with a new gas mixture: a half-hour's operation of the meter at >10% of rating, or, expressed in other terms, 50 to 100 revolutions of the proving head, while passing the new gas, will suffice.

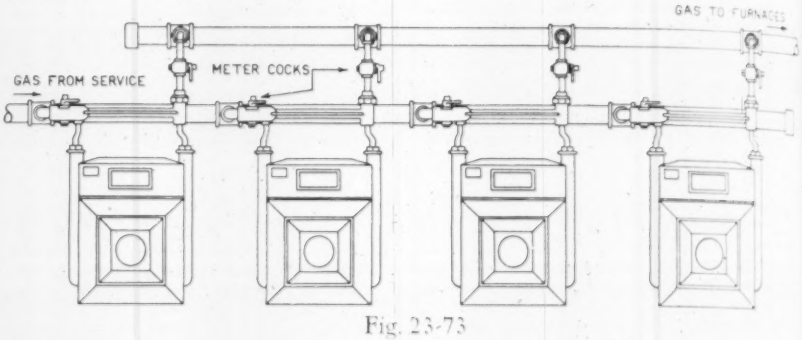

Fig. 23-73

"Definite determination of exact diaphragm leather impregnation formulas to suit specific conditions still awaits the results of extensive tests in active service which are being conducted."—J. Van Norden, Sec'y Am. Meter Co.

From the foregoing, it is plain to see that making brief general statements as to the accuracy of all bellows meters as a class is a venturesome undertaking.

Readings. Without accessories, diaphragm meters furnish registrations of the actual volume passed through, uncorrected for pressure or temperature. Temperature corrections are generally unnecessary between 30°F. and 90°F. Pressure corrections being essential in industrial metering at pressures above a few ounces per sq. in., industrial medium-pressure and high-pressure meters should always be equipped with pressure recorders or, better, with means for automatically converting to standard cubic feet. Other useful devices include demand recorders, etc. Such instruments are described below under "Auxiliary Devices." The meter registers were all of the dial form in the past, but the industrial preference is for "straight reading" cyclometers.

Installation is always simple as regards the mere setting in place and connecting inlet and outlet. Tin case meters hang from their line connections with the use of "meter bars." Iron case meters are set on any flat, firm, dry surface. Where the demand varies considerably it is customary to install a battery of tin case meters rather than one large iron case meter or other large meter, and Fig. 23-73 (from the A.G.A. book "Combustion" by C. G. Segeler) shows a recommended installation. Some precautions are generally necessary in industrial plants to prevent subjecting low pressure meters to excessive internal or external pressure. Fig. 23-74 shows one recommended way of protecting a battery of meters, ahead of a compressor, against collapse from outside air pressure.

(b) Classifications

Bellows meters are ordinarily classified according to their case construction (and consequent working pressure characteristics) into—

(1) Tinned sheet-steel or sheet-iron case meters, usually called tin case meters, all of the Glover type, made in more than twenty sizes with hourly capacities ranging from 150 to 17500 standard cu. ft. (60°F., 30" Hg, saturated) at a pressure drop of 0.5" of gas of 0.64 specific gravity for industrial ratings. In short, strictly low-pressure meters.

(2) Iron or pressed steel case meters. The official A.G.A. designation is "cast iron" with this footnote: "Cast iron, pressed steel or other constructions permitting high pressures." Not all iron case meters are high-pressure meters, however, many of the models—especially in small sizes—being designed for the ordinary distribution systems of some gas companies which, together with governmental agencies, specify cast iron to lessen fire hazard and for various other reasons. It is different with pressed steel meters especially designed for medium and high-pressure industrial applications.

With this exception, the dividing lines are somewhat shadowy, some tin case meters being called industrial on account of their large size only. A more convenient classification therefore, is to omit domestic meters and consider diaphragm meters to be divided into "low-pressure industrial" and "high-pressure industrial" meters. Thus will they be dealt with separately below. The latter, of course, cannot be of tin case construction.

Iron or pressed steel case meters are frequently specified for metering gas from low-pressure utilities systems to industrial plants where compressors are installed. Compressor suction is the determining factor, tin case meters having been known to collapse under atmospheric pressure the moment anything goes wrong with the vacuum regulator.

Allen D. MacLean thus summarizes the principal arguments for tin case and for iron case meters: "The tin meter adherent points to light weight, relatively slow motion, completely equipped repair shops adapted to this type, and a long and noble ancestry. The iron meter man counters with resistance to damage, resistance to external corrosion, compactness, and elimination of soldering in repairing. Between these two none but the foolhardy will dare to make a decision."

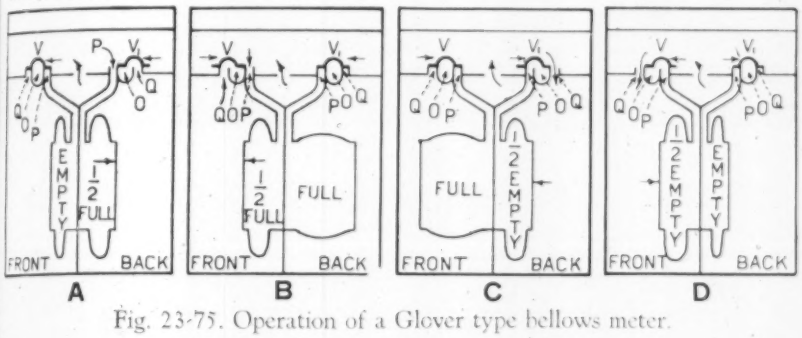

Fig. 23-75. Operation of a Glover type bellows meter.

These diagrams show the relative positions of valves and diaphragms at the four points of cut-off viewed from outlet side. The tangent arm and crank revolve clockwise. (From the Am. Gas Ass'n handbook by G. A. Lane and W. A. Castor.)

(c) Ratings of Low-Pressure Meters

The same basis is used for rating domestic and industrial low-pressure meters, namely, the number of standard cubic feet of 0.60 specific gravity gas which a meter will pass at a pressure drop across the meter of half an inch of water = 0.018 lb per sq. in. This extremely low absorption was specified in the old days of very low distribution pressures and of gas-light mantles that flickered with the pulsations of house line pressure occurring at each diaphragm stroke of our grandfathers' meters. It has its advantages, though, among them a rate of wear of meter parts so slight that if it were not for deterioration of diaphragms and other parts, many low-pressure meters would not need to be inspected oftener than every twenty years. Most of the pressure loss at normal rates of flow occurs through the valve ports, not as a result of mechanical energy consumption. It follows that wear would become a serious factor at excessive rates of flow, in consequence of higher gas pressure on valves, causing in turn greater loads on all bearings—neither valves nor bearings being designed to withstand severe service.

Only the tin case meters have been rated systematically, and the different manufacturers do not all follow the same system, but "convention more or less adheres to the schedule of rating and numbering" in Table XXIII-3.

TABLE XXIII-3—CAPACITIES OF TINCASE BELLOWS METERS AT 0.5" DROP

(American Gas Association)

Designation	Rated capacity cu. ft./hr.	Size of pipe connection, in.	Designation	Rated capacity cu. ft./hr.	Size of pipe connection, in.
5 B	150	½	5 A	175	½
10 B	300	¾	10 A	375	¾
20 B	450	1	20 A	600	1
30 B	600	1¼	30 A	875	1¼
60 B	1300	1½	60 A	1500	1½
100 B	1800	2	150 A	3400	2½
150 B	3000	2½			
200 B	3100	2½	6 C	600	1¼
250 B	4500	3	11 C	1120	2
500 B	7500	6	25 C	2580	2½
			40 C	4000	3
			60 C	6000	4
			170 C	17500	8

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Dial-type Flow Indicator

Dial and Mercury column types... These Indicators are applicable for indication of flow-rates of water, oils, chemicals, air, gas and steam under wide range of conditions.

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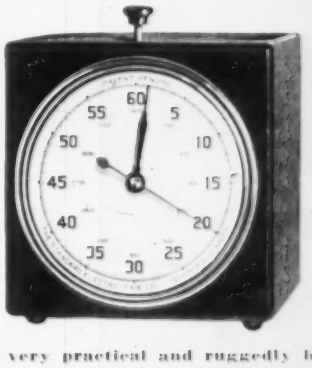

A very practical and ruggedly built instrument specially designed to secure instantaneous dead heat action of the hands, thus insuring extreme accuracy.

One hand has speed of 1 RPM and the other 1 RPH. The 3½" dial with scale divisions of 1/5 seconds makes possible rapid and accurate readings.

Synchronous driving motors can be furnished for any commercial frequencies. A reset to zero plunger is mounted on top of case.

The instrument is equipped with extension cords for connection to current, and with manual starting and stopping switch.

The Standard Electric Time Company
Springfield, Mass.

Write for Prices—State Voltage and Frequency.

NEW INSTRUMENTS

Write Information Section, Instruments Publishing Company, for additional information.

Flow Indicator

The Foxboro Co.

COMPACTNESS and low initial and upkeep costs are among the characteristics of this new Indicating Differential Gage. It has been designed for the many applications where flow meters and automatic rate-of-flow controllers have not yet been installed, and where, consequently, manual control is still relied on. In all such cases it does away with the uncertainty of counting valve turns. The standard scale reads in

percent of total flow and beneath its graduations is a white strip for marking special notations for the guidance of unskilled operators. Option: scales calibrated in actual flow, when data are supplied. Mechanically, the manometric parts are similar to those of the regular (recording) Foxboro flow meters.

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Trans-O-Meter

Westinghouse Elec. & Mfg. Co.

INDICATING the transparency of flat materials on a direct-reading instrument is the purpose of this new portable equipment. The unit is simple, weighs only 8 lbs., operates from 115 volt lamp socket, and consumes but 200 watts. The principle employed consists of measuring the amount of light a 25 watt lamp will pass through the sample. The emergent light falls on a "Photox cell" connected to a microammeter calibrated to read transparency directly in percentage. The Photox cell is of the photovoltaic type. It consists of a specially treated copper oxide disk, responds rapidly without fatigue, and has a spectral sensitivity characteristic which approxi-

(d) Rating High Pressure Industrial Meters

Manufacturer's ratings are nominal, being ordinarily given for two differentials, 0.5″ and 2.0″, both low. The capacity of a high pressure industrial meter, however, should preferably be based on its wear resistance and other characteristics as functions of pressure. Even when a meter is operating at the comparatively low pressure of 5 lb per sq. in., the pressure loss itself is of no consequence as far as the industrial user is concerned.

The assumption that the pressure loss is the only important factor (the outer case of the meter taking care of the working pressure up to 500 lb per sq. in. when so required) is plausible but incorrect. Pressure loss depends not only on the rate at which the gas flows through the meter, but on the density of this gas, which in turn depends on its specific gravity and on its pressure. Moreover, the allowable pressure loss (at which wear is insignificant) varies inversely as a function of the speed at which the meter operates (curve discussed below).

The principal factors affecting the capacity of a high-pressure industrial meter, then, are as follows:

1. Line pressure,
2. Pressure loss,
3. Specific gravity of the gas,
4. Density of gas (in the meter),
5. Meter speed,
6. Wear of valves, etc.,
7. Deformation of parts: diaphragm deflection, etc.,
8. Lubrication.

The first four factors are inter-dependent by reason of the gas laws and of the empirical laws of flows through restrictions; all eight of them are more or less inter-dependent. When all are taken into account, various allowable maximum register speeds are found for each model of meter.

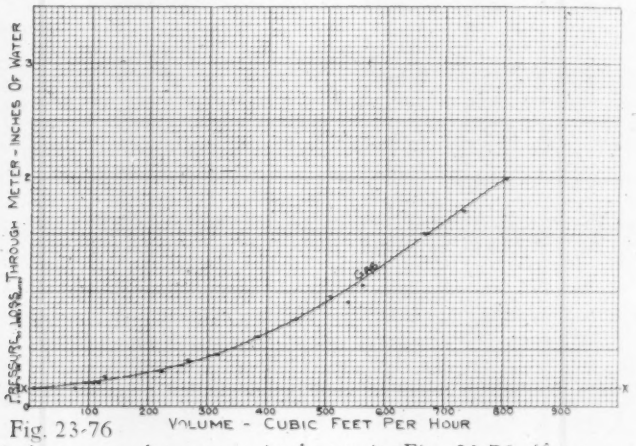


Fig. 23-76

A typical pressure loss curve is shown in Fig. 23-76 (from a paper by MacLean). The intersect at X on the origin of abscissa shows this particular meter to have a "mechanical loss" of 0.15″ of water. Using XX as the origin of pressure loss ordinates we have a curve following closely that of pressure loss through a flow restriction (see Chap. XXV) so that the differential varies as the density of the gas and as the square of the rate of flow. Now, in any mechanism, if the load is high, the speed must be kept down, and vice versa. From these considerations, MacLean has laid down curves for load-speed ratios, one of which is the heavy-line curve in Fig. 23-77. This was derived from tests by the Pittsburgh Equitable Meter Co. of (1) diaphragm deflection and consequent measuring-chamber errors at varying *differentials* and (2) wear at varying *loads* and *speeds*. The load being directly proportional to the differential, it is possible, for any given density, to combine a curve such as that of Fig. 23-76 with the heavy curve in Fig. 23-77 to obtain a guide for determining maximum operating speed. Fig. 23-77 in its entirety gives a series of such guides, whereby any of the meters listed can be rated.

As an example of the use of this method of rating high pressure meters let us assume an installation in which the gas pressure is 40 lb gage (54.7 lb abs.). If the specific gravity of the gas is 0.45, the density is $0.45 \times \frac{54.7}{14.7} = 1.67$. By interpolating between the 1.6 and the 1.7 density curve, we find that the capacity rating line is crossed at the point marked "A" on Fig. 23-77. The allowable pressure loss is 3.75″ of water and by dropping down to the capacity line, we find that a meter rated at 10,000 feet per hour (at 2″ of 0.6 gas) can be operated at 8120 cu. ft. register speed per hour; the meter

whose rating is 5000 feet can be operated at 4060 feet, etc. This rating is expressed in register speed, i.e., actual gas through the meter *at meter pressure*.

The allowable register speed of the largest meter was found to be 8120 cu. ft. per hour at 40 lb gage (54.7 lb abs.). If we assume a pressure base of 4 oz. and an atmospheric pressure of 14.7, we have an absolute base pressure of 14.7 + 0.25 = 14.95 lb per sq. in. Since the volume according to Boyle's Law varies inversely as the absolute pressure, 8120 feet becomes $8120 \times \frac{54.7}{14.95} = 29{,}700$ cu. ft. per hour.

Similarly, reducing to normal atmosphere, the maximum allowable register speed of the meter, 8120 cu. ft., corresponds to 30,215 standard cubic feet per hour.

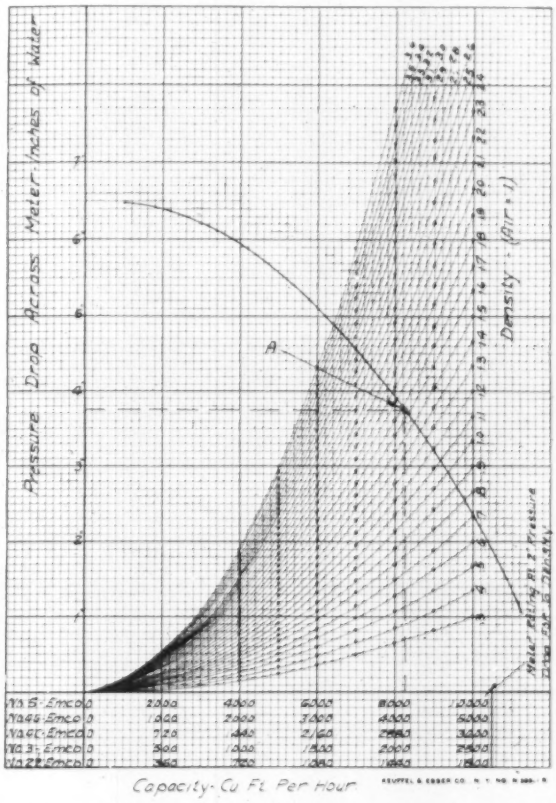


Fig. 23-77

Diehl first discussed mathematically in his *Positive Displacement Meters* the inter-relations of differential, register speed, pressure, etc., and also the testing of high-pressure meters, giving handy formulas and tables. Since the publication of that Am. Meter Co. book in 1930 he has of course kept up his researches. Under date of June 27, 1933, he sends us a curve (Fig. 23-78) of maximum meter (register) speeds for satisfactory performance, based on actual field experience and tests of high-pressure meters; and a table of maximum capacities of seven sizes of meters (Table XXIII-4), also the result of experience.

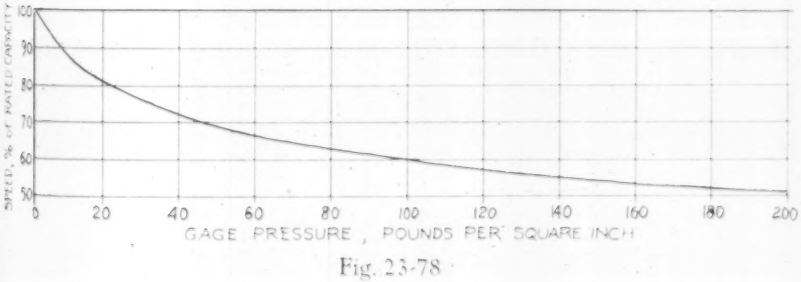
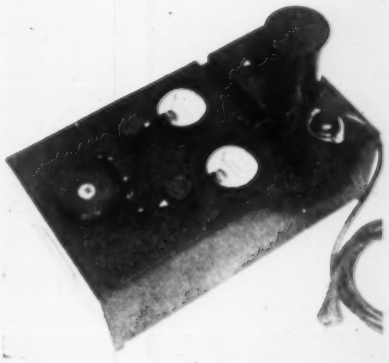


Fig. 23-78

To use Fig. 23-78, simply multiply the nominal rating (capacity in cu. ft. of 0.6 specific gravity gas at 0.5" differential) by the percent for the gage pressure of the gas to be metered. Then, to obtain the maximum allowable rate in *standard* cubic feet, apply Boyle's law as above.

As for Table XXIII-4, it can be used directly for selecting high-pressure meters when the specific gravity of the gas to be metered is around 0.6; and for gases of other specific gravities Diehl recommends using the following factors:

Specific Gravity	0.4 (manufactured gas)	1.0 (air)	1.17 (Butane-air)
Factor	1.1	0.88	0.85



mates that of the human eye. The Trans-O-Meter is built in a light steel case which contains the Photox cell, the microammeter, the Trans-O-Meter lamp, and a voltage regulator to insure even illumination from the lamp. The cell terminals are connected to the microammeter through a potentiometer which provides a sensitivity adjustment for the microammeter to widen the new instrument's range of applications.

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Altitude Regulator

The Electric Controller & Mfg. Co.

AUTOMATIC control of motor-driven pumps is the function of this regulator. The new model is enclosed in a Bakelite case which insulates the unit, making it shock-proof. The adjustable indicators are now supplied in different colors; the high limit contact being red and the low limit contact green.

These are set from outside by individual flush type adjusting screws. This regulator makes possible very close regulation of liquid levels. For example, with a 0-50 ft. scale, a motor-driven pump can be started and stopped so as to hold the water level within 1 ft. between the high and low limit contacts. Should closer regulation be desired, a 25-50 ft. scale would be supplied to permit 6" regulation.

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"Super-Meg" Tester

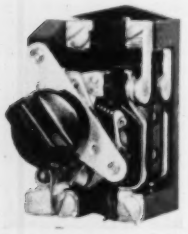
James G. Biddle Co.

THIS new addition to the "Megger" line, designated as No. 680 Wide Range Super-Meg, should find application in industrial plants where high voltages are used, also by railroads and public utilities. Its ranges are 0 to 200 and 0 to 2000 megohms, the latter being twice as high as that of the widest-range previous model.

Starting Switch for Fractional Horsepower Motor

General Electric Co.

A SMALL, hand-operated starting switch, providing complete protection against stalled-rotor current and injurious overload conditions, has been developed for use with either single-phase a-c. or d-c. fractional horsepower motors. The a-c. switch is available in single and double-pole forms. The new switch affords complete overload protection, a positive snap-action mechanism which is trip-free on overload, and adaptability for mounting in purchasers' enclosures. All molded parts are made from Textolite. Contact tips are pure silver. Metal parts resist corrosion. Underwriters' listing has been obtained. The new CR1061 switch has been made available in several forms: open-type switches for applications where the purchaser wishes to provide his own enclosure; enclosed-type switches for general purpose applications; and switches for Class 1, Group D hazardous locations. The one illustrated (with case removed) is for a.c. motor control, 2-pole, 1 overload, 0.5 h.p., 110-220 volts single phase.



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Precision Level

The R. Y. Ferner Co.

READING 5 seconds of arc per division, this high precision level, recently brought out by the Société Genevoise d'Instruments de Physique, is particularly adapted to shop use, for checking machine tools and high speed transmissions, setting sine bars on inclined surfaces, leveling base plates and beds of machinery, and manufacturing tools and fixtures. The body, of hard steel machined from the solid, is insensible to shocks and protects the level vial against temperature fluctuations and hand heat. The base, $6\frac{1}{2}$" x $1\frac{3}{16}$", is carefully scraped and provided with cleaning grooves. The level vial is cemented in a brass mounting which is adjustable by means of a knurled screw. This permits setting the vial to zero, using the level for slightly tilted surfaces (desirable in checking the ways of machine tools that are not exactly leveled) and measuring progressive tilts beyond the graduations. The spacing of the vial divisions is about 0.1" and there are 4 each side of zero so that the total capacity is 40 seconds of arc. Net weight is 2.1 lbs.; finish is black enamel.

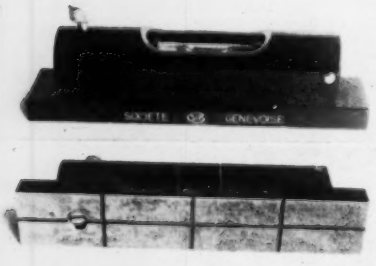

TABLE XXIII-4—MAXIMUM HOURLY CAPACITIES OF HIGH PRESSURE METERS EXPRESSED IN CUBIC FEET OF 0.6 SPECIFIC GRAVITY GAS AT STANDARD PRESSURE

(Compiled in June, 1933, by John C. Diehl)

Pressure pounds gage	Rated capacity of high pressure meters in cubic feet per hour						
	1,000	1,500	2,000	2,500	4,000	6,000	
10	1500	2200	2900	3700	5900	8800	
20	1900	2900	3800	4800	7600	11000	
30	2300	3500	4600	5800	9200	14000	
40	2700	4000	5400	6700	11000	16000	
50	3000	4600	6100	7600	12000	18000	
60	3400	5100	6800	8500	14000	20000	
80	4000	6100	8100	10000	16000	24000	
100	4700	7000	9300	12000	19000	28000	
120	5300	7900	11000	13000	21000	32000	
140	5800	8800	12000	15000	23000	35000	
160	6400	9600	13000	16000	26000	38000	
180	6900	10400	14000	17000	28000	42000	
200	7500	11000	15000	19000	30000	45000	

MAXIMUM ALLOWABLE CAPACITY OF LARGE IRON CASE METERS WHEN USED WITH BUTANE-AIR, NATURAL AND MANUFACTURED GAS AT PRESSURES UP TO 100 LBS. PER SQUARE INCH.

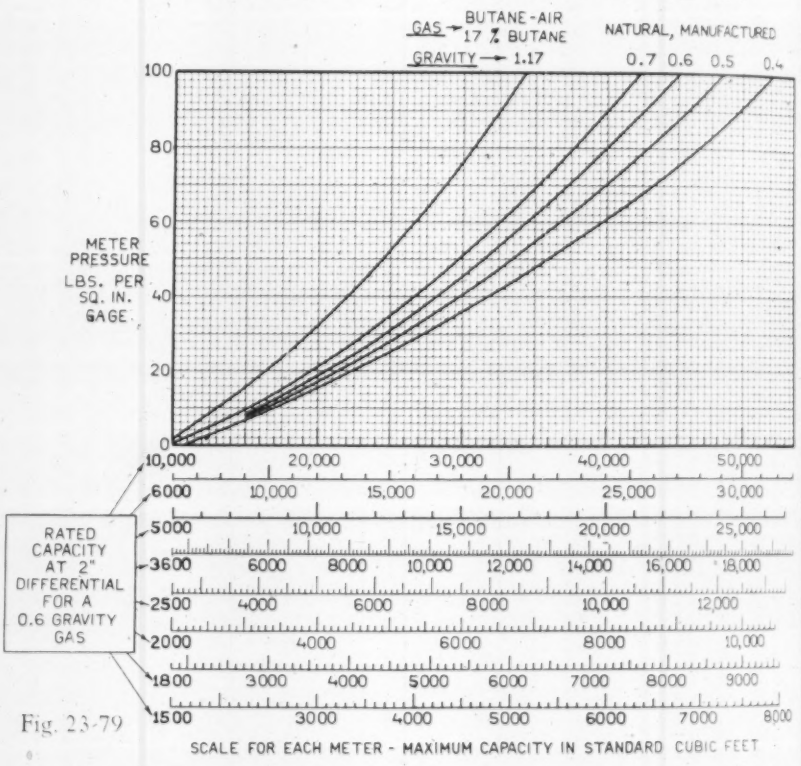

Fig. 23-79

Wear resistance, and other factors discussed above, were taken into account in the preparation of the American Gas Association's chart, Fig. 23-79, by C. G. Segeler. This chart is devised for the purpose of selecting high pressure industrial meters of large capacity for various operating conditions. There are five curves for various values of specific gravity from 0.40 to 0.70, covering the usual kinds of manufactured and natural gas, and an additional curve for a specific gravity of 1.17 for the normal butane-air mixture. The several scales read directly in maximum capacity *measured in standard cubic feet* which the meter could pass when operating at the pressure. Segeler's chart, therefore, is still another guide to selection of high-pressure industrial meters.

Summing up briefly: what damages many high-pressure meters in industrial plants is not high static pressure but the *combination* of high speed and high differential. The widespread impression that 2" is the highest allowable differential is erroneous: for low operating speeds an 8" loss might be the limit, and at high speed a 2" loss might cause excessive wear.

Rectox High Sensitivity Instruments

By B. R. Hill*

HERETOFORE, the practical measurement of alternating currents has been made by 3 types of instruments, namely, electrodynamometer, repulsion or attraction iron vane, and thermocouple-d'Arsonval. Now we have a fourth type known as the Rectox. It consists of a copper oxide rectifier and a d'Arsonval type instrument. The a.c. is rectified and then measured by the ordinary d.c. d'Arsonval instrument. The energy consumption of the previous types of a.c. instruments is much more than for d.c. instruments in which the magnetic field is supplied from a strong permanent magnet, permitting a comparatively small current in the moving coil. The higher energy consumption of a.c. instruments has been an application handicap for a long time, especially where the energy consumed by the instrument would seriously change the circuit conditions, as in radio measurements. The Rectox instrument has successfully solved this problem by embodying the high sensitivity features of the d'Arsonval type in an a.c. instrument. The rectifier units are copper plates oxidized on one side. These allow current to flow much more readily from the oxide to the copper than from the copper to the oxide. The plates are assembled, held in place under constant pressure by a clamp, and the entire unit is impregnated to seal it from moisture.

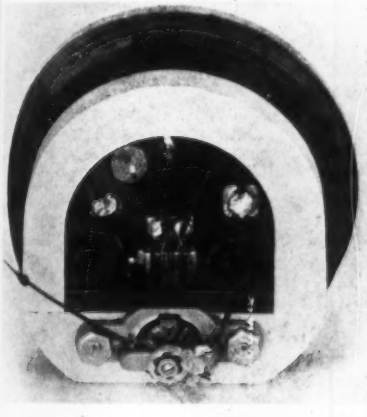

Fig. 1

These rectifier units, considerably smaller than the usual battery charging unit, give full wave rectification for all instrument applications. This is accomplished by the 4-section arrangement shown in Fig. 2. The Rectox instrument has certain operating characteristics which makes its application to a.c. measurements somewhat critical. These are as follows:

(1) The torque and deflection of the Rectox are proportional to the first power of the current. Therefore, it measures the average value and not the effective value of the a.c. wave. The scale is, however, calibrated to read effective or root mean square values of a pure sine wave. Errors on other than sine wave forms can be compensated for in readings provided the wave form is known from which a correction factor can be applied, or the instrument may be calibrated on the wave form with which it is used.

*Instrument Division, Westinghouse Electric & Mfg. Co.

(2) The resistance of the Rectox is a function of the current flowing. For example, a Rectox milliammeter scaled to 20 m.a. has a resistance of approx. 1750 ohms at 0.2 m.a., 650 ohms at 1 m.a., 185 ohms at 5 m.a. and 100 ohms at full-scale current. Not only does a rectifier type milliammeter affect the circuit conditions on account of its added resistance like any other instrument, but the effect depends upon the actual current value pass-

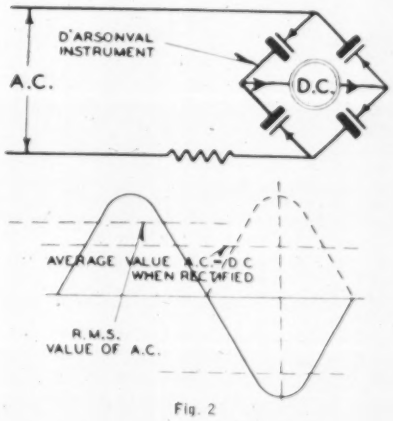

Fig. 2

ing. If the circuit resistance is relatively high then this change will result in negligible effects. The instrument always correctly indicates the actual current passing through it, but this may depend upon the non-linear value of the instrument resistance.

(3) The readings may be expected to decrease about 0.5% per kilocycle up to 35000 cycles where different conditions occur. Due to capacity effects this type of instrument is not recommended for radio frequency measurements. It is, however, reasonably accurate throughout the audio frequency bands.

(4) The resistance of the copper-oxide unit is a function of temperature, and the amount of change due to temperature depends on the amount of current passing. Due to the complex relation between current, temperature and resistance, a great deal of skill is required in designing a Rectox instrument to prevent errors arising from temperature changes.

(5) Like all devices of its kind, the efficiency of the copper-oxide rectifier is less than 100%; in other words, if 1 milliampere a.c. is passed through it the resulting rectified current available for operating the indicating instrument is usually <0.8 m.a.

(6) Finally, the current efficiency ratio (d.c. current output divided by a.c. current input) is affected to some extent by temperature and also by the absolute value of current flowing. This again results in a complex situation involving temperature, current and efficiency, and a simultaneous study of all of these variables is the only means by which errors from temperature variations can be minimized.

Most of these errors can be minimized by careful design and by taking advantage of the opposite effects of certain errors. However, it is important that the instrument be properly designed to operate with the copper oxide rectifier. It therefore is inadvisable to try to apply a copper oxide rectifier to an existing d'Arsonval instrument which has not been designed for this application.

The chief advantage of a rectifier instrument is in its high sensitivity. By use of the rectifier principle, a.c. voltmeters may be made with a very high resistance per volt. Standard voltmeters are available in ratings as low as 4 volts with 1000 ohms per volt, 15 volts with 2000 ohms per volt and even 0.5 volt with 5000 ohms per volt resistance. Below 4 volts rectifier voltmeters should have a resistance of 2000 and better still 5000 ohms per volt, in order to properly compensate for the errors discussed above. Milliammeters and microammeters of low ratings are also available. Rectifier instruments are continually finding new uses in radio work. Further developments in research and engineering on these instruments will tend to minimize their present errors and make them still more useful.

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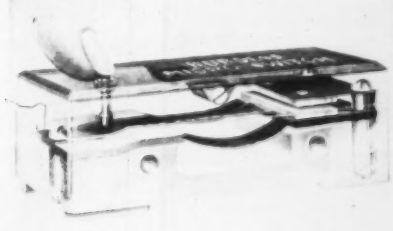
Heavy Duty Micro Switch

C. F. Burgess Laboratories, Inc.

LESS than 0.000021 ft.-lbs. of energy suffices to operate this new trigger switch although its 110 volt a.c. rating is 10 amps. A 0.001" movement of the button makes the silver contact plates snap together or fly apart. A 14 oz. initial pressure causes operation; when this pressure is reduced to 10 oz., reverse operation takes place; thus the 4 oz. differential multiplied by the 0.001" motion gives 0.004 inch ounce as the required operating energy. Suitable leverage is used when the available force is small, as in household appliances. For example, with a 20:1 lever, the motion remains small (0.02") but the differential force need only be 0.2 oz. so that the switch can be actuated reliably by a delicate clockwork or by a tiny, inexpensive bit of bi-metallic strip. The most significant advantage of this minimal energy consumption in the field of Instrumentation is that accurate automatic control is made possible with small, weak and inexpensive primary elements. For example, a thermostat requiring a differential of 10° F. to cut-in and cut-out may be made to control within 0.5° F. by substituting this new micro-switch for the usual types of snap switches, which are extremely "stiff" in comparison. To insure maximum service, 2 relatively costly materials are used in the micro switch—silver for the contact plates and beryllium copper for the springs. The use of beryllium copper for springs is new, but successful. Its electrical conductivity is high. Heavy currents can be passed through it without seriously altering the desired physical characteristics. In recent tests beryllium copper springs and phosphor bronze springs were flexed 10 times a second. All phosphor bronze samples failed in less than 800,000 cycles,



all beryllium copper samples survived 15,000,000 cycles without signs of deterioration.

Operation of the micro switch depends upon producing a sufficient change in the relative forces of two opposing spring systems to cause the contacting silver plates to separate or to come together with a positive snap action. In the normal position of the switch, the moving element mounted on the main spring system is held definitely against the upper limiting stop. In the case of the normally closed switch, this stop is the stationary electrical contact, while in the normally open unit it is an insulating stop. A positive, quick "snap" action is obtained both in making and breaking the electric circuit, even at high speeds. Large silver contacts provide the dissipation of heat required to assure long life under heavy loads.

Contained in a dust-proof molded phenolic case, the micro switch measures 1 15/16" long, 11/16" wide and 27/32" high. The body is black. Colored tops identify the type: red top, normally closed; green top, normally open; blue top, double-throw. All types are single-pole. The switch is entirely free from vibrational effects. Mounting (any position) is effected by 2 No. 6 machine screws. Screw terminals are on the bottom of the case. Ratings are 10 amps., 110 volts; 5 amps., 220 volts; a.c. Temperatures up to 300° F., even for long periods, do not affect the materials used.

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Time Temperature and Time Pressure Controllers

The Bristol Co.

THE introduction of new time-temperature and time-pressure controllers, recently announced, is reported to be due to the success of the "Bristol's Free Vane" air-operated pressure and temperature controllers, combined with the demand by industry for controlling pressure or temperature according to a predetermined rate of change. In many processes, it is desired to regulate a temperature or pressure by either increasing it or decreasing it at some predetermined rate. These new controllers will do this, on any range of temperature from —40 to 1000° F., or pressure from 10 to 2000 lbs./in.² Fig. 1 shows Model 8040 MT Controller, large cam type. The cam here consists of a sheet aluminum chart which is cut by the user to give any desired time schedule within the limits of the instrument. The cam is driven by either a Bristol Telechron electric clock or by a spring clock. Air supply and controlled air line gages are mounted self-contained, and the whole is enclosed in a compact moisture-proof aluminum case. Fig. 2 shows the Model 7240 MT, which is similar except that it is equipped with an indicating pointer which shows at all times the instantaneous value of the pressure or temperature. The Free Vane pilot air valve allows the instrument to control without loading the indicating pointer at any time. The cam is automatically driven and can be readily changed. Both instruments are finding many process control applications.

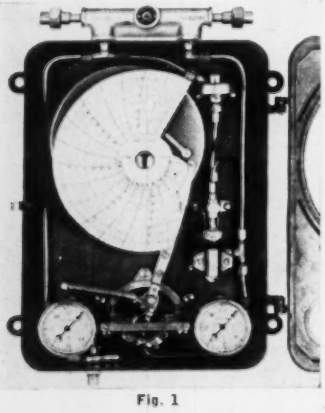


Fig. 1

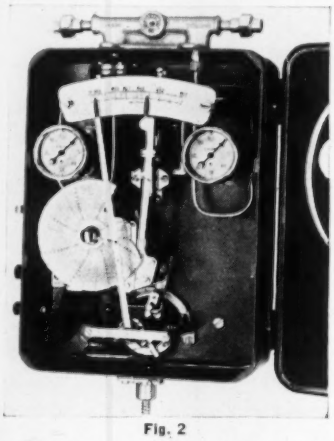
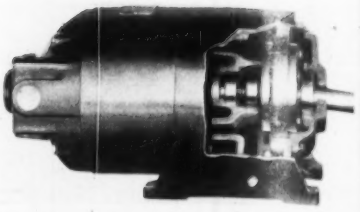


Fig. 2



Fractional Horsepower Gear-Motors

General Electric Co.

FRACTIONAL horsepower gear-motors, with the characteristics and construction of the latest designs of general purpose motors, combine light-weight, efficient, high-speed motor drive with a simple compact reduction gear to give almost any desired speed at the output shaft, a liberal oil capacity and a complete lubrication system. Full access to the gear mechanism is possible by removal of the cover plate. These motors are available in 2 types, both in ratings from 1/6 to 3/4 h.p.: a concentric shaft type (illustrated) with speeds from 500 to 98 r.p.m., and a right angle shaft type, with speeds from 200 down to 11 r.p.m. Planetary type of gearing with concentric shafts are utilized in the smaller ratios and worm gears singly or in combination with the planetary type in the higher ratios. Gear case, shafts, gears, and bearings are designed with a generous factor of safety.

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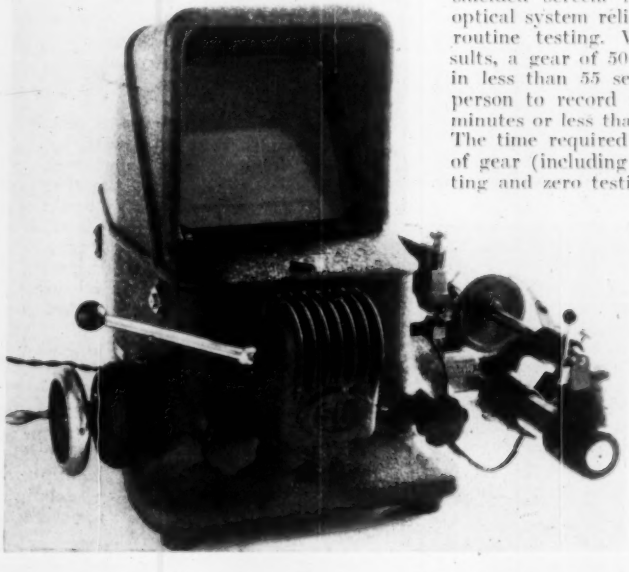
Optical Gear Tester

The R. Y. Ferner Co.

DEVELOPED by the Société Genevoise d'Instruments de Physique, of Geneva, Switzerland, this new equipment differs from most projection instruments in that it *measures* the pitch and eccentricity of small gears. The rectangular shadow of a signal plate is thrown on a graduated screen. Variations of eccentricity are read on the horizontal scale; errors of pitch on the vertical scale, both directly to 0.0002" and by estimation to 0.00005" (guaranteed accuracy ± 0.0001"). The apparatus is essentially an instrument for rapid routine testing of gears up to 4" diam. and down to 0.16" diam. Feelers (the contact anvils with which to make settings in the teeth of the gears) can be supplied for diametral pitches up to 160 (module of 0.25 mm.), or for a maximum diametral pitch of 10 (module of 2.50 mm.). The signal plate, cemented between two glass plates to avoid dust accumulation on edges (dust on glass surface being out of focus), is held in the focus of a microscope with large-aperture objective and projection ocular, and its shadow projected onto an optically flat mirror and from thence to the shielded screen. A green filter in the optical system relieves the user's eyes in routine testing. Without recording results, a gear of 50 teeth can be checked in less than 55 seconds; with a second person to record results, in less than 4 minutes or less than 5 seconds per tooth. The time required to set for a new size of gear (including adjustments, zero setting and zero testing) is 2 minutes; for changing to another gear of the same size and resetting zero, 30 seconds. This gear tester, designated as VE-6, meets the need of makers of fine machinery, clockwork, meters, recorders, optical instruments, telemeters, chronographs, motion picture apparatus, artillery fire control instruments, etc.



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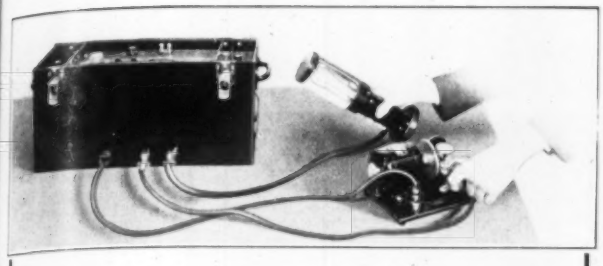

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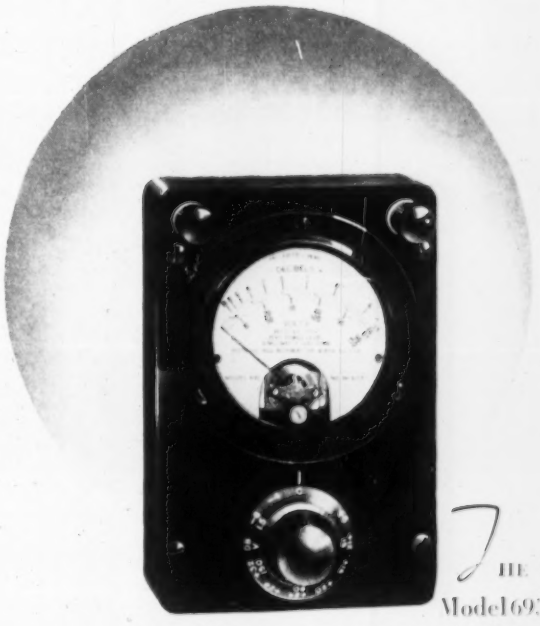

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